

1 that are associated with the use of diffusion or
2 turbulent flame burners in compact reformer apparatus.

3 However, there are practical limitations
4 regarding the use of an annular reaction chamber for
5 small-scale reformers having hydrogen production rates
6 of less than about 1500 SCFH. It is well known that
7 the heat transfer coefficient of gaseous reactants
8 contained within an annular reaction chamber is
9 directly related to the velocity of the gaseous
10 reactants within the annular space. In order to limit
11 the reaction chamber wall temperature, the velocity of
12 gaseous reactants within the annular space must be
13 sufficiently high to absorb the radiant heat flux that
14 impinges on the reaction chamber tube walls. However,
15 for very small-scale reformers, this requires that the
16 width of the annular reaction chamber space be small.
17 It is common practice in the art to limit the maximum
18 diameter of the catalyst particles packed within an
19 annular space to less than 20 percent of the width of
20 the annular space in order to ensure that the catalyst
21 is evenly distributed within the reaction chamber and
22 to prevent gas channeling along the walls of the
23 reaction chamber. However, for an annulus having a

1 small width dimension, this requires use of catalyst
2 particles of particularly small diameters thereby
3 resulting in an undesirably high pressure drop through
4 the catalyst bed.

5 The benefits of a flameless radiant burner
6 for use in compact catalytic reaction apparatus of
7 annular reaction chamber geometry are known. For
8 small-scale reformer applications, a tubular reaction
9 chamber geometry is preferred over annular reaction
10 chamber geometry in order to simultaneously achieve
11 high heat transfer coefficients and low pressure drops
12 within the reaction chamber.

13 There is need for a compact endothermic
14 catalytic reaction apparatus as embodied in the
15 present invention to achieve the objects of compact
16 design, while avoiding the problems of flame
17 impingement, excessive reaction chamber wall
18 temperatures, and excessive reaction chamber pressure
19 drop by application of a tubular reaction chamber that
20 is heated by the radiant burner. The tubular
21 endothermic reaction chamber as disclosed herein
22 employs a combination of catalyst particle sizes and
23 reactant mass velocities to control the reactor

1 pressure drop and the maximum reaction chamber tube
2 wall temperature within certain needed limits; and the
3 radiant burner is operated at specific ranges of
4 combustion intensity and excess air to control surface
5 temperature of the radiant burner within certain
6 needed limits. The present invention extends the
7 practical range of tubular endothermic reaction
8 chamber geometry that can be used in combination with
9 radiant burners for converting hydrocarbon feedstock
10 to useful industrial gases.

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12 **SUMMARY OF THE INVENTION**

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14 It is the general object of this invention
15 to provide a novel endothermic catalytic reaction
16 apparatus for the production of industrial gases from
17 a hydrocarbon or methanol feedstock that is
18 simultaneously compact, thermally efficient, has
19 improved life expectancy and low pressure drop, and is
20 particularly well suited for the small scale
21 generation of useful gases for fuel cell applications
22 in the range of 1 k W to 50 k W.